IoT Workshop

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What is IoT

What is an IoT Device?

- Constrained in (one or more of):
  - Memory
  - CPU
  - Network bandwidth and/or latency
  - Storage
- Has connectivity

IoT Devices - Example chips

Protocol	Chip	Specs
Bluetooth 4/5	nRF52x	32-64 MHz, Cortex-M0/M4F, 24-256k RAM, 192-1024 k Flash, $1.88-$3.85
WiFi	ESP8266/ESP32	80MHz-160MHz, 1-2 cores, ~80k RAM, < $1 - $4.53
LoRa	Semtech	$3.23 - $4.74

ESP8266 Specifications

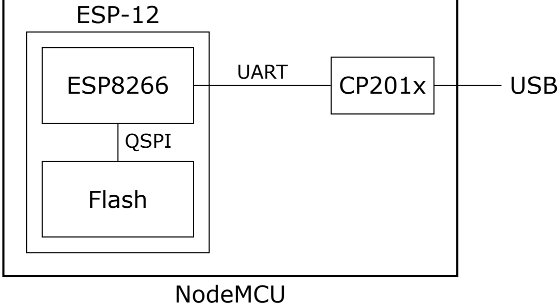
CPU	Tensilica Xtensa L106
Frequency	80MHz (160MHz possible
RAM	32 kB instruction RAM 80 kB user RAM 16 kB system RAM
Flash	None, integrated SPI driver
Peripherals	16 x GPIO I^{2}C, SPI, I^{2}S, UART 10 bit ADC Wi-Fi

ESP8266 Power usage

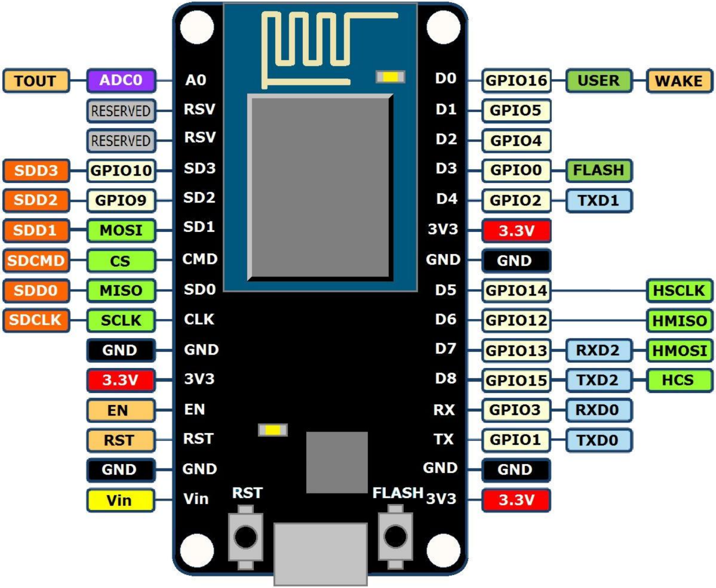
State	Current usage
Off	0.5 μA
Deep sleep with RTC	20 μA
Light sleep (with Wi-Fi)	1 mA
Sleep with peripherials	15 mA
TX	170 mA

NodeMCU

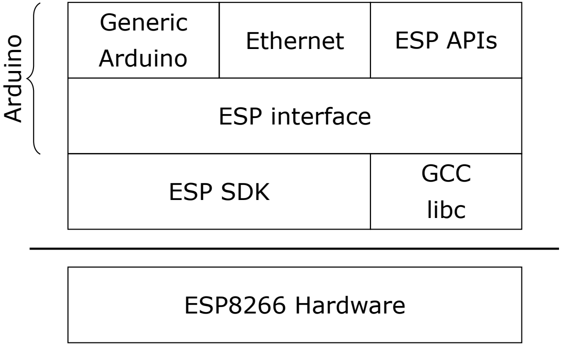
NodeMCU hardware



NodeMCU hardware



ESP8266 software layers



Arduino

Generic Arduino

Ethernet

ESP APIs

ESP interface

ESP SDK

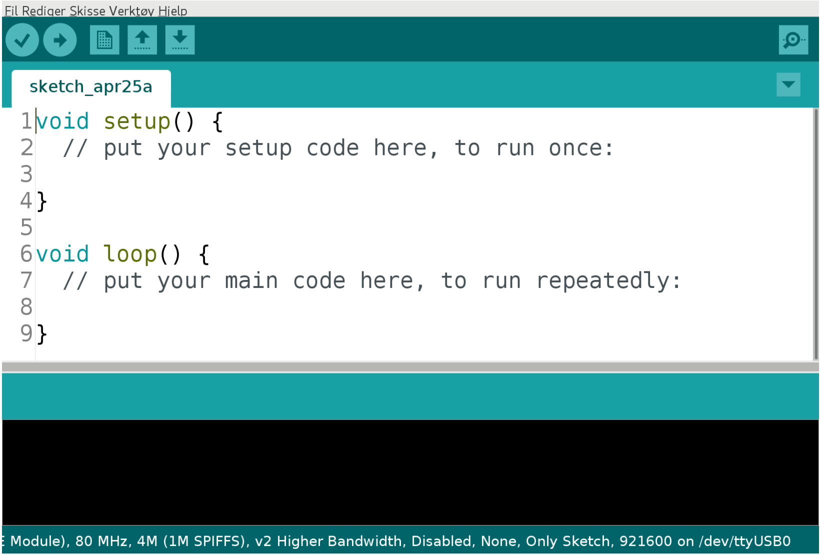
GCC libc

ESP8266 Hardware

ESP8266 + Arduino

- Standard Arduino IDE
- ESP8266 Arduino core
  - https://github.com/esp8266/Arduino

Arduino IDE



```
void setup() {
  // put your setup code here, to run once:

}

void loop() {
  // put your main code here, to run repeatedly:

}
```

E Module), 80 MHz, 4M (1M SPIFFS), v2 Higher Bandwidth, Disabled, None, Only Sketch, 921600 on /dev/ttyUSB0

Generic Arduino APIs

```
// Pin: D0, D1, etc.
// Mode: OUTPUT, INPUT, INPUT_PULLUP
// State: HIGH, LOW, 1/0

void pinMode(pin, mode);
void digitalWrite(pin, state);
int digitalRead(pin);

unsigned long now = millis();
unsigned long now = micros();
```

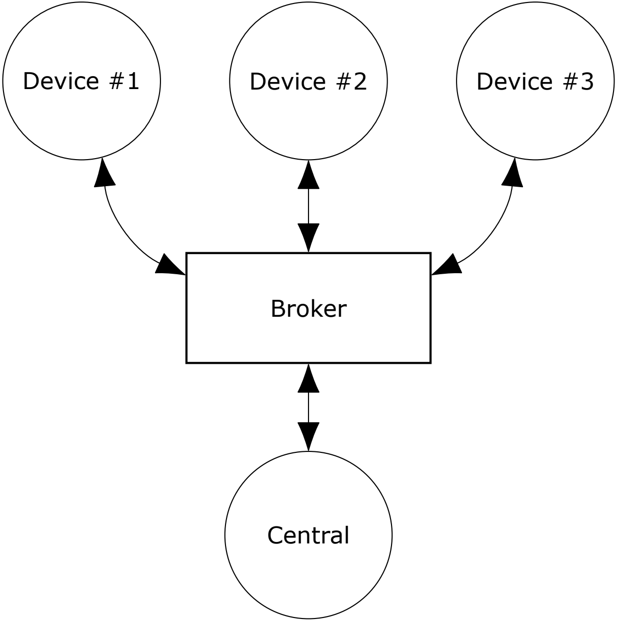
Assignment: `blink-a-led`

Lecture: MQTT

MQTT

- *Message Queuing Telemetry Transport*
- Wikipedia: MQTT

Device and application architecture with MQTT



MQTT Example

The temperature sensor:

- Publishes on:
  - `myapp/$device-id/temperature`
  - `myapp/$device-id/humidity`
  - `myapp/$device-id/altert`
- Subscribes to:
  - `myapp/$device-id/command`

The central application:

- Subscribes to:
  - `myapp/#/temperature`
  - `myapp/#/humidity`
- Publishes on:
  - `myapp/$device-id/command`

MQTT - The protocol

Agents have one of two roles:

- *Client*
  - Publishes *messages*
  - Subscribes / unsubscribes to *topics*
  - Keep alive
- *Broker* (aka Server)
  - Handles network connections
  - Keeps subscriptions
  - Manages client
    - Timeouts and disconnects
    - *last will*
  - Persistence of *retained* messages

MQTT - The protocol - MQTT Topic

- Topic name: `foo/bar/baz`
- Topic filter
  - `foo/bar/?`
  - `foo/#`

ESP Arduino APIs

```
class {
    void restart();
    uint32_t getFreeHeap();
    uint32_t getChipId();

    ...
} ESP;

// Usage
ESP.restart();
```

Connecting to a Wi-Fi

```
#include <ESP8266WiFi.h>

void setup() {
    WiFi.mode(WIFI_STA);
    WiFi.begin("NDC2018", NULL);

    while (WiFi.status() != WL_CONNECTED) {
        delay(500);
        Serial.print(".");
    }

    Serial.println("");
    Serial.println("WiFi connected");
    Serial.println("IP address: ");
    Serial.println(WiFi.localIP());
}
```

MQTT on Arduino

PubSubClient is our MQTT client implementation.

Preparing to publish messages:

```
#include <ESP8266WiFi.h>
#include <PubSubClient.h>

WiFiClient wifiClient;
PubSubClient mqtt(wifiClient);

String deviceId = "esp-" + String(ESP.getChipId(), HEX);

void setup() {
    // ...
    mqtt.setServer("broker.hivemq.com", 1883);
}
```

MQTT on Arduino

```
void loop()
{
    if (!mqtt.connected()) {
        reconnect();
    }
    else {
        mqtt.loop();
    }

    // Do work
}
```

MQTT on Arduino

```
void reconnect()
{
    do {
        Serial.println("Connecting to MQTT");
        delay(1000);
    } while (!mqtt.connect(clientId.c_str()));

    Serial.println("Connected to MQTT server");
}
```

MQTT on Arduino

```
void sendMessage()
{
    String topic = "ndc/" + deviceId + "/led";
    mqtt.publish(topic.c_str(), "1");
}
```

MQTT on Arduino

Preparing for subscriptions:

```
void setup() {
    ...
    mqtt.setCallback(callback);
}

void callback(char* topic,
              byte* payload,
              unsigned int length) {
}

void reconnect() {
    ...
    // Subscribe to any topics you need
    mqtt.subscribe(topic_pattern);
}
```

Assignment: `mqtt-with-button`